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## Correspondence

### Structure of orbitofrontal cortex predicts social influence

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Some people conform more than others. Across different contexts, this tendency is a fairly stable trait [1]. This stability suggests that the tendency to conform might have an anatomical correlate [2]. Values that one associates with available options, from foods to political candidates, help to guide choices and behaviour. These values can often be updated by the expressed preferences of other people as much as by independent experience. In this correspondence, we report a linear relationship between grey matter volume (GM) in a region of lateral orbitofrontal cortex (IOFC<sub>GM</sub>) and the tendency to shift reported desire for objects toward values expressed by other people. This effect was found in precisely the same region in each brain hemisphere. IOFC<sub>GM</sub> also predicted the functional hemodynamic response in the middle frontal gyrus to discovering that someone else's values contrast with one's own. These findings indicate that the tendency to conform one's values to those expressed by other people has an anatomical correlate in the human brain.

In an earlier study [3], we found that the brain's functional hemodynamic response to another person's preference for an object, and the impact of that preference on the brain's reward response to receiving that object, correlated with the subject's tendency to conform self-reported desire for objects to preferences expressed by others. This highlighted some physiological

dynamics of social influence on value in the brain, but did not address the structural foundations that would link social influence to developmental and evolutionary theory. Moreover, we could not reliably investigate the blood oxygenation level dependent (BOLD) signal from orbitofrontal cortex (OFC) because of signal dropout and distortion in the region. Lesion studies suggest that OFC is causally involved in central components of social influence on value. Damage to this region impairs one's ability to correctly assign value to stimuli, respond appropriately to social cues, and act appropriately during social interaction [4–7]. To investigate the relationship of OFC structure to social influence in healthy individuals, we can use volumetric based morphometry (VBM) methods, which are unaffected by signal dropout and distortion. That is, we can test for a correlation between GM of the OFC and the tendency to conform value to the preferences of others in the same 28 adult subjects (15 male) of our previous study [3] (see Supplemental Experimental Procedures in the Supplemental Information available on-line).

A week prior to testing, subjects provided the names of twenty pieces of music that they would like to own, but did not own yet. On the test day, subjects rated each submitted song for desirability, from 1 (low) to 10 (high). Next, subjects were told that two music ‘reviewers’, of whom subjects had read descriptions and rated as capable of choosing enjoyable music, had listened to each song; the subjects then performed the task illustrated in Supplemental Figure S1. During a trial, subjects indicated their preference, given a choice of a song they had submitted and an alternative song, which they had never heard. Subjects were then told which song the reviewers preferred. Each submitted song was evaluated relative to six alternatives. After the task, subjects rerated their desire for each submitted song. Change in desire was tested for a linear relationship with net reviewer preference for the song (times preferred – times not

preferred). The resulting coefficient,  $B_{inf}$  (M 0.091, SD 0.17), provided a measure of tendency to conform values to values expressed by the reviewers for each subject [3].

Using VBM, we tested the relationship between  $B_{inf}$  and OFC GM. Age, gender, total brain GM and  $B_{inf}$  were entered into a multiple regression to OFC GM using T1-weighted MRI images.  $B_{inf}$  was linearly related to GM in a specific lateral OFC region ( $lOFC_{GM}$ ) in both hemispheres (Figure 1A,B). No other regions correlated with  $B_{inf}$  in a separate whole-brain search, even at a reduced statistical threshold. A functional analysis (see Supplemental Experimental Procedures and Data) found that like  $B_{inf}$  [3],  $lOFC_{GM}$  predicted the functional hemodynamic response to disagreement with the reviewers about song value, in the middle frontal gyrus (Figure 1C).

This is new evidence of an anatomical correlate of social influence on value. Surprisingly, the correlate was found in lateral rather than medial OFC regions that are typically associated with monitoring option value [6]. This likely relates to the precise conformity-related mechanism mediated by  $lOFC_{GM}$ . Such a mechanism may well affect non-social learning too.  $lOFC$  is particularly tuned to punishment, when option values need updating [6, 7].  $lOFC_{GM}$  predicts frontal responses to social disagreement about value. Therefore,  $lOFC_{GM}$  could index the salience of social disagreement or interpretation of that disagreement as a punishing event that requires an update of values. It could also index the ability to credit detected changes of value to the correct song option [7].

$lOFC_{GM}$  could reflect a single psychological trait that directly corresponds to behavior ranging from conformity to anticonformity (for example, affinity for group membership). On the other hand, it is possible that conformity and anticonformity are mediated by two separate mechanisms. For example,  $lOFC_{GM}$  could mediate only

conformity-related cognition that, when reduced, allows anticonformity-related cognition to have a greater impact on behavior (negative  $B_{\text{inf}}$  coefficients). It seems unlikely that conformity and anti-conformity are completely independent given that functional and anatomical correlates span the whole range of positive and negative  $B_{\text{inf}}$  values [3] in a single brain region. However, this possibility is consistent with results obtained in a subsample of 23 subjects with  $B_{\text{inf}}$  scores near zero or above, and in all 28 subjects when anticonforming changes of value are coded as independence (no change) (see Supplemental Information). The precise conformity-related cognition associated with  $\text{IOfC}_{\text{GM}}$  is now an enticing question for future research.

These new findings carry implications for many fields. Clinically, changes in social conduct that result from atrophy or damage to prefrontal cortex [4,6] might result from a reduced tendency to adopt values expressed by others. In addition, expansion of prefrontal cortical grey matter may play a role in the tandem changes of social learning during primate evolution and development [8–10].

### Supplemental Information

Supplemental Information includes experimental procedures, two figures, and supplemental data and can be found with this article online at \*bxs.

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Figure 1. Structural and overlapping functional correlates of social influence.

Statistical maps are overlaid onto a standard MNI brain at coordinates: -40mm, 33 mm, -14mm.

(A) OFC regions in which GM correlated with social influence on value ( $B_{inf}$ ) (threshold  $p < 0.001$ , FWE corrected at  $p < 0.05$ ; right peak 36mm 33mm -10mm,  $P_{FWE} = 0.023$ ,  $T = 5.56$ , 73 voxels; left peak -33mm 28mm -16mm,  $P_{FWE} = 0.029$ ,  $T = 5.43$ , 183 voxels. (B) Mean GM value (a.u.) within the entire right cluster (red triangles) and entire left cluster (blue circles) plotted against social influence on value ( $B_{inf}$ ). GM values were mean corrected within each cluster. (C)

Overlap (green) in middle frontal gyrus functional activity predicted by conjunction of IOFC<sub>GM</sub> and B<sub>inf</sub> during disagreement with experts (vs. agreement) about object value (peak: -40mm 46 mm 4 mm,  $Z = 3.72$ , 768 voxels).

## Supplemental Information

Document S1. Experimental Procedures, Two Figures and Supplemental Data.

**Figure 1**

